U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB-253 317

ASSESSMENT OF NOISE EXPOSURE PRODUCED BY CHANGE IN APPROACH PROCEDURE AT LOS ANGELES INTERNATIONAL AIRPORT

BOLT BERANEK AND NEWMAN, INCORPORATED

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

SEPTEMBER 1973

BOLT BERANEK AND NEWMAN INC

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161049

PB 253 317

BBN Report 2590

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By

Richard D. Horonjeff

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Contract No. 68-01-1835

Submitted to:

Office of Noise Control Programs
U.S. Environmental Protection Agency
Crystal Mall Building No. 2, Room 1107
Washington, D.C. 20460

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U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

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TABLE OF CONTENTS

		Page
I.	INTRODUCTION	1
II.	FIELD MEASUREMENTS	4
	A. Site Selection	4
	B. Noise Data Acquisition and Analysis	5
III.	ANALYTIC PROCEDURES	6
IV.	RESULTS	8
	A. Effects of Ocean Approaches East of Airport	8
	B. Effects of Ocean Approaches on Noise Environment Northwest of Airport	10
	C. Background Noise Measurements	11
V.	CONCLUSIONS	13
TABLES		
FIGURES		
REFERENCES		
APPENDIX		

I. INTRODUCTION

Modifications of aircraft approach and takeoff procedures can be a relatively inexpensive means for achieving potentially great changes in the noise exposure of communities bordering airports. If inexpensive operational changes (such as two segment approaches, night curfews, re-routings of flight patterns, etc.) lighten aircraft noise impact in a community, they would deserve serious consideration as methods to alleviate the noise problem. To date, however, no well documented evidence of the effectiveness of operational changes in modifying community response to aircraft noise has been produced.

On April 29, 1973, Los Angeles International Airport (LAX) inaugurated a revised approach procedure between 2300 and 0600 hours (weather permitting). This revised procedure takes full advantage of the airport's proximity to the ocean and light traffic conditions by routing both inbound as well as outbound flights over the ocean during the late night and early morning hours. By so doing, residents living under the normal approach pattern to LAX experience a total curfew of aircraft activity during this time period.

At the request of the Environmental Protection Agency, Bolt Beranek and Newman Inc. (BBN) has undertaken a study to document any changes in noise exposure resulting from the revised procedure.

The purpose of this report is to document these changes. This change in noise exposure will be dependent on numbers of aircraft overflying populated areas rather than any change in aircraft noise level itself. The current level of activity at LAX varies between 1600 and 2000 movements (departures plus arrivals) per day. Of this total, approximately 35% are short haul (less

than 1000 miles) and 65% are long haul operations. There are approximately 130 arrivals during the period of 2300 to 0600. Jet traffic accounts for over 95% of all operations.

Figure 1 shows the airport and vicinity and depicts normal daytime traffic patterns. The airport has two sets of two parallel runways. The north complex (Runways 24L&R/6L&R) and the south complex (Runways 25L&R/7L&R) have a lateral separation of one mile, thus permitting simultaneous approaches and departures. The proximity of the ocean results in a prevailing westerly wind. Thus, approximately 98% of all traffic moves in the east to west direction. Departing aircraft climb out over the ocean and cross back over the shoreline after attaining an altitude approximately 6000 feet. Approximately 70% of the departures use the south runway complex and 30 percent use the north complex. Arriving aircraft approach over the city from the east. Approximately 70% of the aircraft use the south complex, and 30% use the north runway complex. All aircraft in excess of 350,000 pounds must use the north complex so as not to jeopardize the structural integrity of the Sepulveda Boulevard vehicular undercrossing of the south complex.

The land area to the east of the airport which is exposed to overflights of approaching aircraft is primarily residential in nature. There is little doubt that portions of this residential community are high noise exposure areas. The new approach procedure was instituted in an effort to reduce the noise exposure in this area. Figure 2 depicts the night traffic routings. Briefly, the procedure involves routing approaching aircraft over the ocean and allowing them to make their final approach over water from the west. Minimum aircraft altitude over populated land areas is approximately 6000 feet using this procedure. Departing aircraft are unaffected and continue to make their departures to the west. The entire procedure is described in Reference 1.

There are several geographic areas in which the procedure affects the noise environment[2]. Normal daytime routing of inbound flights from the north and west is in an easterly direction over the Santa Monica airport, with a right turn in the vicinity of Los Angeles Coliseum. The elimination of night flights on this path results in less exposure to parts of Santa Monica, Culver City, the Baldwin Hills area, and to a lesser extent the area south of the Coliseum to Century Boulevard. The most significant benefit is in the areas under the final approach course, particularly within two to three miles of the airport. In this area, aircraft are at an altitude of less than 800 feet.

The area between the airport and the shoreline is subject to some additional landing noise in addition to the normal takeoffs which would not be affected by the new procedure. Similarly, areas to the side of the runways would be exposed to the noise from application of the jet thrust reversers used to reduce the aircraft speed, in addition to the existing takeoffs. A preliminary study[2] indicated that these changes in noise exposure are very moderate in magnitude.

Section II of this report describes the measurement sites and provides the rationale for their selection. Section III provides a description of the analytic methods used in this report. Section IV summarizes the results of the field survey, and Section V presents the conclusions reached in this study.

II. FIELD MEASUREMENTS

A. Site Selection

Two geographical areas were selected for investigation in this study based on (1) the operational details of the new procedure, and (2) a preliminary study[2] of the new procedure prepared for the Los Angeles Department of Airports. The two areas were those which were expected to experience the greatest benefit and greatest impact from the new procedures.

The study of Reference 2 indicated that sizeable land areas under the approach path to Runways 25L and 25R would receive the greatest benefit from the reduction in the number of overflights during the nighttime hours, since the majority of the arriving aircraft use either of these two runways. To document the noise exposure in this area, three noise monitor sites were chosen. These sites are shown in Figure 3. Site 1 is located in a high noise exposure area between the extended centerlines of Runways 25L and 25R. The approaching aircraft are at an altitude of approximately 300 feet in this neighborhood. Site 2 is located in a moderate noise exposure area to the south of the approach path. This site was selected to be in an area where aircraft noise would be of boarderline concern. Reference 3 was used to locate this site in the NEF 30 to 35 range. Site 3 is also located in a moderate noise exposure area. It is located almost directly beneath the approach path to Runways 25L and 25R. Nominal aircraft altitude at this site is 1450 feet. This site, also selected with the aid of Reference 3, is located in an NEF 35 to 40 area. Site 4 is located in an area where the maximum (but probably negligible) increase in noise exposure would be expected. Prior to the introduction of the new procedures, the primary noise impact at this site resulted from departures on Runway 24L. With the new procedures in effect this site also experiences landing noise on Runways 6L and 6R.

B. Noise Data Acquisition and Analysis

The acoustic noise environment was monitored at the four sites on a 24-hour basis using portable noise monitoring units developed by BBN. Each site was monitored for a minimum of a two weeks to obtain a representative picture of the noise environment. In addition to the noise monitoring, records of runway closures were obtained from FAA tower personnel. These closures can have pronounced effects on the measured noise exposure. The dates of noise monitoring along with the runway use data are presented in Figure 1.

The entire noise data acquisition and analysis system is discussed in detail in Appendix A. The hourly (HNL) and daily (DNL) noise exposure summaries tabulated by the system provided the basic data upon which the conclusions of this report are based.

III. ANALYTIC PROCEDURES

To assess the changes in the noise environment resulting from the new operational procedures a single criterion, the Day/Night Average Sound Level (DNL), was used. This section of the report describes the analytic techniques used to determine changes in DNL values resulting from the revised approach procedures.

The noise data analysis procedures used in this study differ slightly for the two geographic areas of interest. In the area east of the airport, the major point of interest is the benefit achieved by eliminating flights which would normally overfly the area during the hours of 11:00 p.m. (2300) to 6:00 a.m. (0600). In the area northwest of the airport, the concern is with any increase in noise exposure resulting from aircraft which would not normally approach the airport from the ocean during the hours of 2300 to 0600.

East of the airport, the benefit to be achieved by the cessation of night overflights was determined on the basis of measurements made before and after the change in procedure. These measurements provided HNL values for each hour of the day over a period of two weeks or more. From the measurements made before the change, energy average HNL values were obtained for each of the 24 hours. A DNL value was then computed from the average HNL's. This DNL value was representative of the noise environment with night overflights. To compute a DNL representative of the noise environment without overflights, the same HNL values were used, with the exception that the HNL's for the hours 2300 to 0600 were replaced by the typical background level HNL's obtained from measurements made after the change. The benefit achieved by the new procedure is the difference in these two DNL values.

In the area northwest of the airport, any adverse effect due to the new procedure would manifest itself as an increase in noise exposure during the hours of 2300 to 0600 with no expected change during the hours of 0600 to 2300. Two DNL values, representative of the noise environment before and after the change in procedures, respectively, were calculated using the following technique. First, a common base of energy average HNL values for the hours of 0600 to 2300 was calculated from all measured HNL's (before and after the change). As an aside, there was no significant difference in the average 0600-2300 exposure. Two sets of average HNL values were calculated for the night period 2300 to 0600. One set was the energy average values of the measurements made before the change; the second set was the energy average values of the measurements made after the change.

To calculate a DNL representative of the environment before the change, the common base 0600 to 2300 HNL's and the energy average 2300 to 0600 HNL's before the change were used. A second DNL, representative of the environment after the change, was calculated from the same common base 0600 to 2300 HNL's but using the energy average 2300 to 0600 HNL's after the change. The difference in these two DNL's provided a measure of the increase in daily noise exposure in this area.

IV. RESULTS

The results of this study are described in two parts. Part A discusses the measurement results in the land area east of the airport where benefit from the ocean approaches is expected. Part B discusses the results in the area northwest of the airport where possible adverse effect from the ocean approaches might be expected.

A. Effects of Ocean Approaches East of Airport

The results from the three noise monitor sites in this area indicate that the cessation of night overflights between the hours of 11:00 p.m. and 6:00 a.m. results in an approximate three decibel reduction in the Day/Night Average Sound Level in the vicinity of the approach to Runways 25L and 25R. This change was sufficiently small such that the depicting of this change through noise exposure contours did not appear warranted. This reduction in the DNL was determined from the analysis procedure outlined in Section III. Table II tabulates the DNL values at all sites. Figures 4, 5 and 6 show the results of this analysis in graphical form. At each site the ensemble of measured HNL values for each hour of the day was energy averaged to determine a representative HNL value for each hour before and after the procedural change. The figures show this variation in hourly noise level over the course of the day. It was anticipated that the cessation of night overflights should manifest itself only in the reduction in the HNL values from 2300 to 0600. This is verified by the HNL values measured after the change.

At Site 1 there appears to be a consistent difference in hourly exposure between the "before" and "after" measurements. It is highly doubtful that this difference can be attributed to a change in nighttime flying procedures. A more plausible explanation lies in the relative utilization of the two parallel runways, 25L and 25R, and in the location of the noise monitor system in relation to the approaches to these runways. Figure 3 shows Site 1 to be located almost directly under the approach to Runway 25L. At this point, aircraft approaching 25R are approximately 300 feet directly overhead, and aircraft approaching 25L are at the same altitude but 700 feet to the north. Based on this distance relationship, the noise exposure at Site 1 would be 5 dB greater for aircraft approaching 25L than for aircraft approaching 25R. Thus, noise exposure at this site is somewhat sensitive to modest variations in the relative utilization of the two runways.

Site 2, which is well to the south of both paths, would by the same calculations experience only a 1.5 dB difference in noise exposure between the two paths. Thus, the noise exposure at this site is relatively insensitive to changes in the relative utilization of the two runways. Similarly, the "before" and "after" curves in this figure do not display the consistent difference observed at Site 1.

The trend at Site 3 suggests the noise exposure for the "after" measurements to be greater than that "before" the changeover. The most probable explanation for this discrepancy lies in the weather conditions during the two monitor periods. Under VFR (visual flight rules) conditions, aircraft arriving from the north will frequently turn onto final approach considerably west of Site 3. Thus, many flights which would normally overfly Site 3 under IFR conditions, might not overfly this site under VFR conditions. For aircraft overflying this site, the exact

flight path followed has negligible influence on the total noise exposure. This is due to the relatively high altitude (approximately 1450 feet) of the aircraft at this site, in relation to any expected lateral dispersion.

In addition to the DNL and HNL values measured at each site the SEL values of the individual aircraft noise intrusions were also calculated. Typical distributions of SEL values are shown in Figures 7, 8 and 9. Distributions for two typical days are shown in each figure. One day is typical of the "before" condition and the other day is typical of the "after" condition. The figure illustrates the typical variation in the day-to-day distribution of SEL values measured during the daytime and evening period. It also illustrates the elimination of significant noise intrusions during the period of 2300 to 0600, after the change in nighttime approach procedures. At Sites 1, 2 and 3 no aircraft noise intrusions during these hours were monitored after the change in procedure. Similarly, Figures 10, 11 and 12 show typical distributions of maximum noise levels (A-weighted) from the same flights shown in the SEL figures. These figures show the absolute magnitude of sound levels experienced from aircraft flyovers at each of the sites.

B. Effects of Ocean Approaches on Noise Environment Northwest of Airport

Results from the noise monitor site in this area indicates that the introduction of ocean approaches results in a 1.7 dB increase in noise exposure in the area northwest of Runways 24L/6R and 24R/6L. Reference 2 suggests that this is a localized phenomenon and is limited to the area north and west of the approach end of Runways 6L and 6R. Thrust reverser noise in the area along the runway sideline is of negligible effect.

The 1.7 dB increase was determined based on measurements performed at Site 4 before and after the procedural change using the analytic procedure outlined in Section III. Average hourly noise level (HNL) values for the two measurement sessions are plotted in Figure 13. Note that the HNL values for the hours of 0600 to 2300 are in reasonably good agreement, while there is a systematic increase in the HNL values after the change between 2300 and 0600. Thus, there is reason to believe that the increase in nighttime noise exposure is a result of the increased number of landings on 6L and 6R and is not due solely to the discrepancy between two random samples.

In addition to the long term noise exposure expressed by the DNL and HNL, the SEL values for individual noise intrusions were calculated at the site. Distributions of SEL values for two typical days (one "before" and one "after") are shown in Figure 14. Note that the figure shows a slight increase in the number of noise intrusions during the late night and early morning hours after the change in procedure.

In a like manner, Figure 15 shows typical distributions of maximum A-levels for each of the noise intrusions reported in Figure 14. This figure gives an indication of the absolute magnitude of the aircraft noise level produced in the community.

C. Background Noise Measurements

In addition to measurements of aircraft noise, a limited number of on-site measurements were made of the ambient noise level in the absence of aircraft. The results of these measurements indicate that the background level is quite consistent at all four measurement sites. HNL values for the late night and early morning hours range from 45 to 50 dB. In comparing these background

noise levels with the HNL values presented in Figures 4, 5, 6 and 13, it is apparent that aircraft noise intrusions control the total noise environment (DNL) at all four sites.

V. CONCLUSIONS

The rerouting of aircraft approaches during the late night and early morning hours results in a modest decrease of 3 dB in the Day/Night Average Sound Level (DNL) in the vicinity of the approach paths to Runways 25L and 25R; at the expense of this decrease, a very minor increase of 1.7 dB in the DNL northwest of the airport results. The study also shows that the change in procedure brought about the desired results:

- complete elimination of night overflights east of the airport
- consistent day-after-day elimination of overflights
- consistent day-after-day reduction in daily noise exposure for a large segment of the noise impacted population, with negligible increase in noise exposure for a small segment of the noise impacted population.

TABLE I

NOISE MONITOR SCHEDULE

Date	Measurement Site 1	2	3	4	Runway Closures
4 April	x		x	x	Eastward traffic 6:52-19:45
5 "	x		x	x	
6 "	x		x	x	
7 "	x		x	x	
8 "	x		x	x	
9 "	x		x	x	24L, 7:30-15:30
10 "	x		x	x	24L, 7:30-15:30
15 April	x		x	x	
16 "	x		x	x	
17 "	x		x	x	
18 "	x		x	x	
19 "	x		x		25L, 10:50-11:07, 20:00-24:00
23 April	x	x			25L, all day
24 "	x	x			25L, all day
25 "	x	x			25R, 15:01-15:16
25 "	x	x			25L, all day
27 "	x	x			
21 May	x	x			25L, all day
22 "	x	x			25L, all day; 25R, 2:56-4:20; 24R, 5:30-6:11
23 "	x	x			25L, all day
24 "	x	x			25L, all day
25 "	x	x			25L, 0:00-6:00
26 "	x	x			
27 "	x	x	x	x	
28 "	x		x	x	
29 "	x		x	x	25R, 9:06-9:27
30 "	x		x	x	
31 "	x		x	x	
1 June	x		x	x	
2 "	x			x	

TABLE II

DAY/NIGHT AVERAGE SOUND LEVELS,
BEFORE AND AFTER REVISED APPROACH PROCEDURES

	Measurement Site			
	1	2	3	4
After	81.5	67.1	69.0	76.9
Before	84.4	70.7	72.2	75.2
Net Change	-2.9	-3.6	-3.2	+1.7

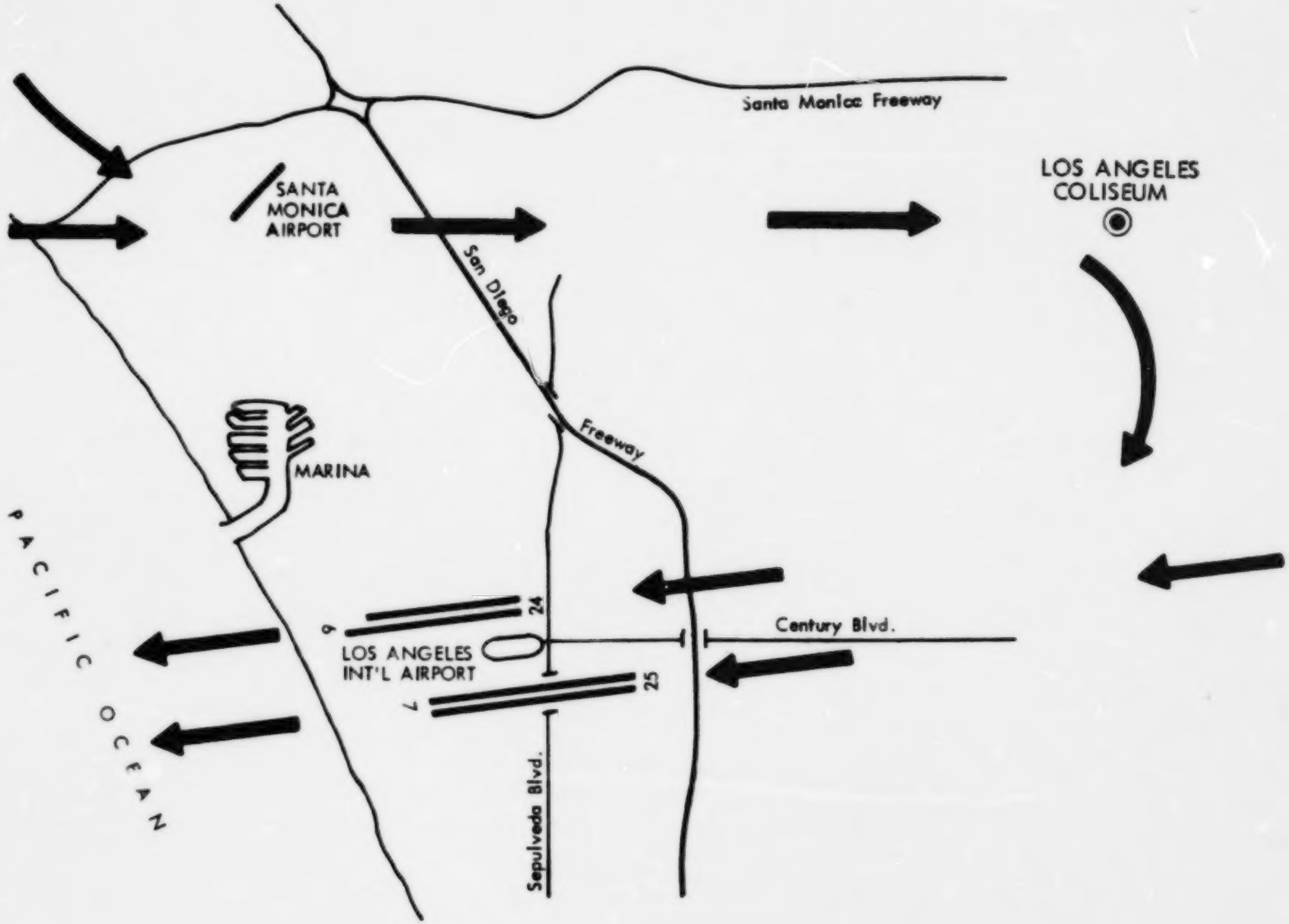


FIGURE 1. TYPICAL DAYTIME AIR TRAFFIC PATTERN AT LOS ANGELES INTERNATIONAL AIRPORT

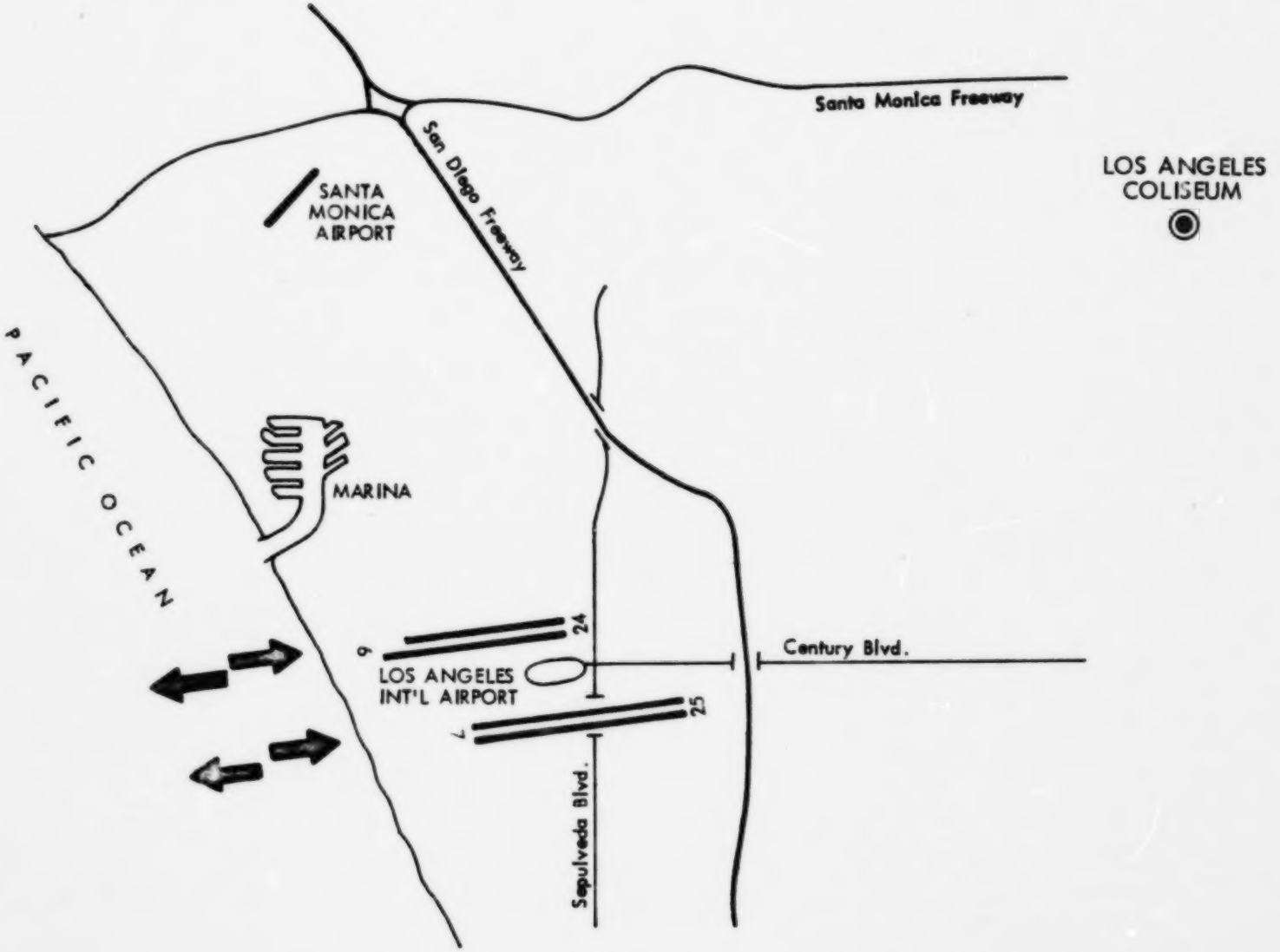


FIGURE 2. TYPICAL NIGHTTIME AIR TRAFFIC PATTERN AT LOS ANGELES INTERNATIONAL AIRPORT

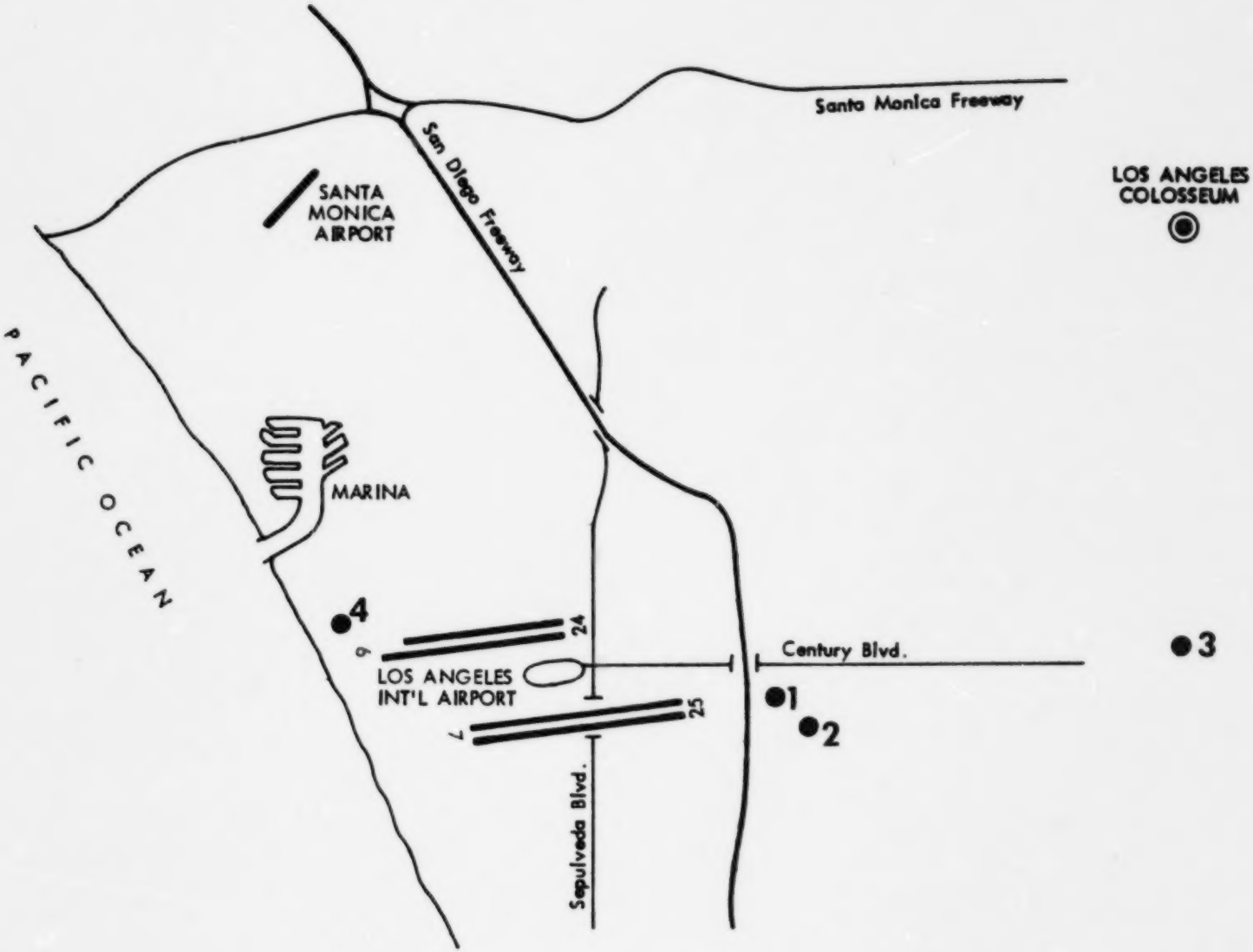


FIGURE 3. NOISE MONITORING SITES

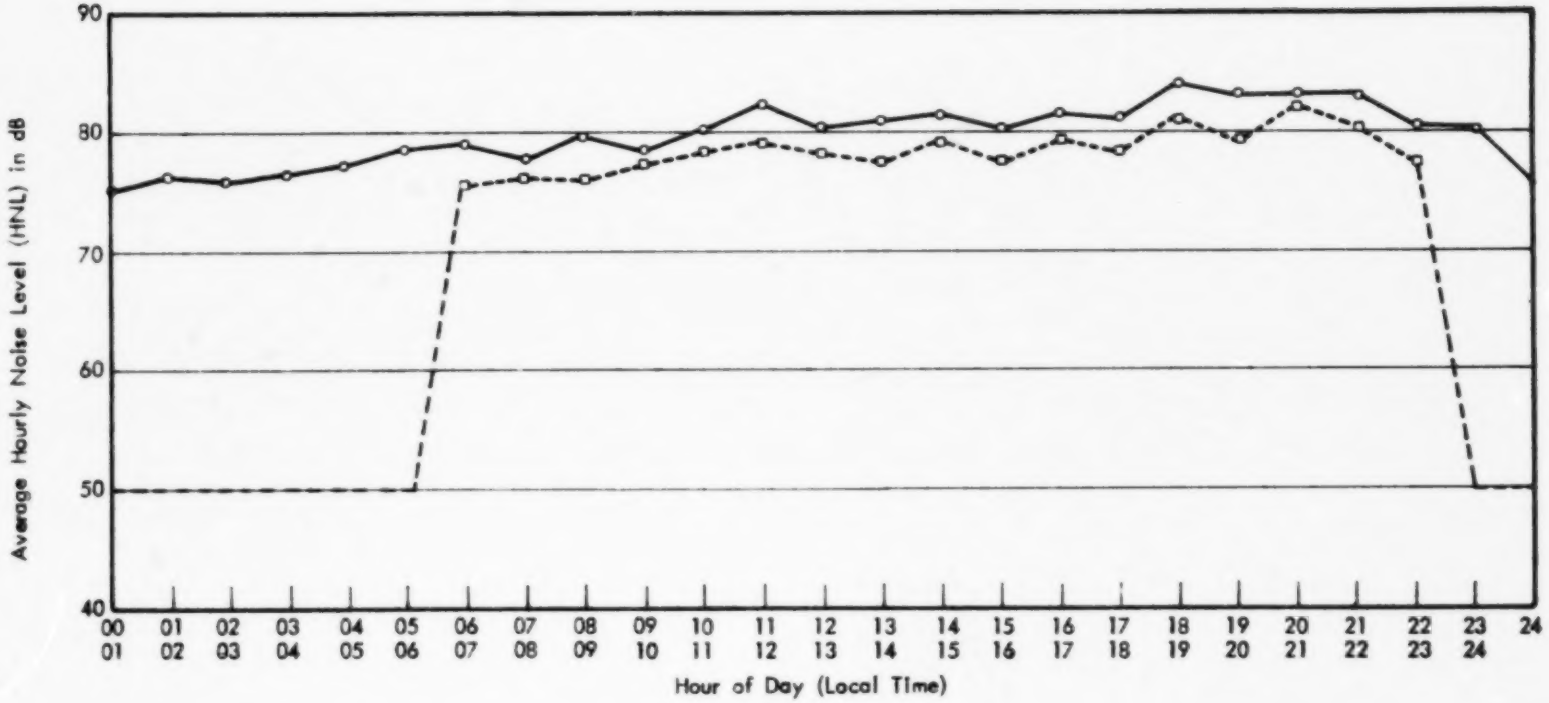


FIGURE 4. VARIATION IN HOURLY NOISE LEVEL FOR SITE 1

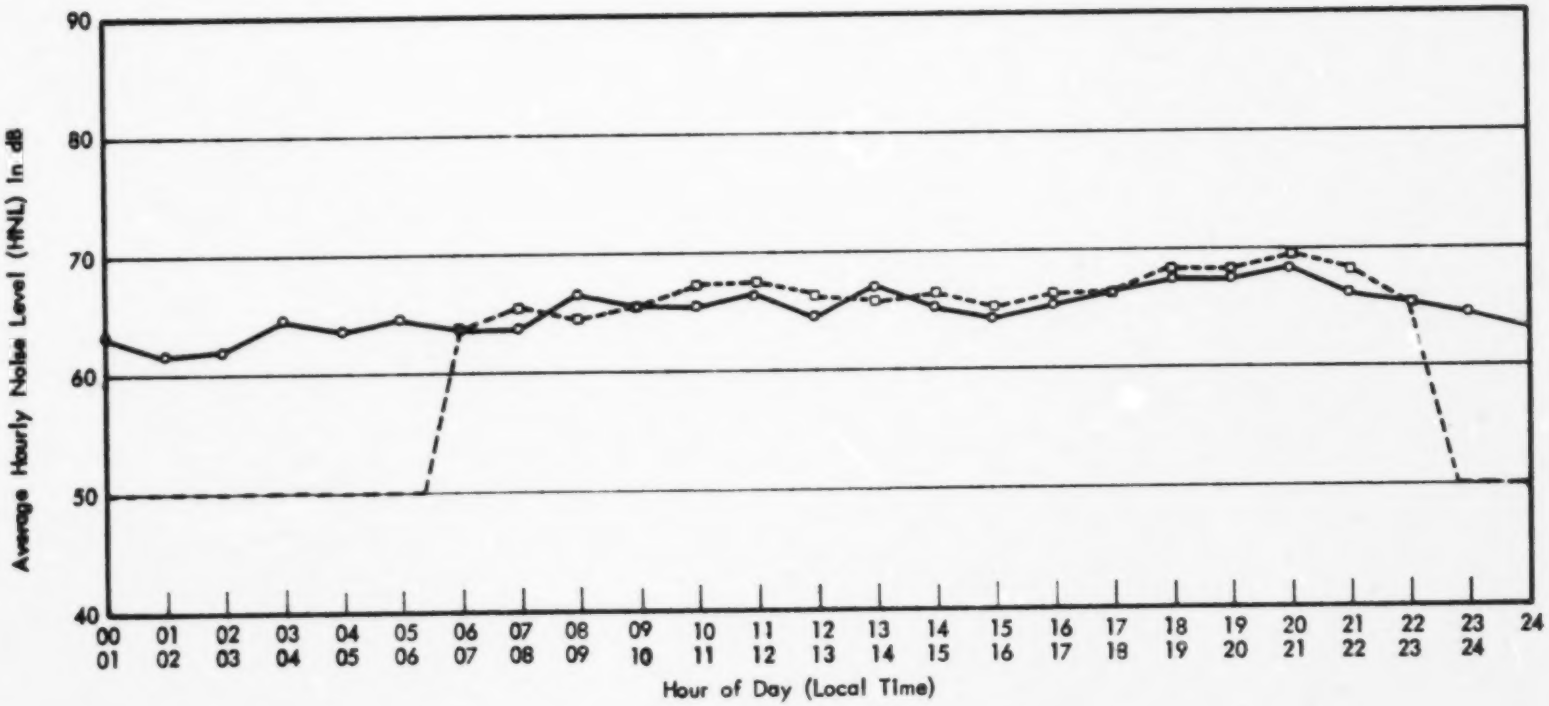


FIGURE 5. VARIATION IN HOURLY NOISE LEVEL FOR SITE 2

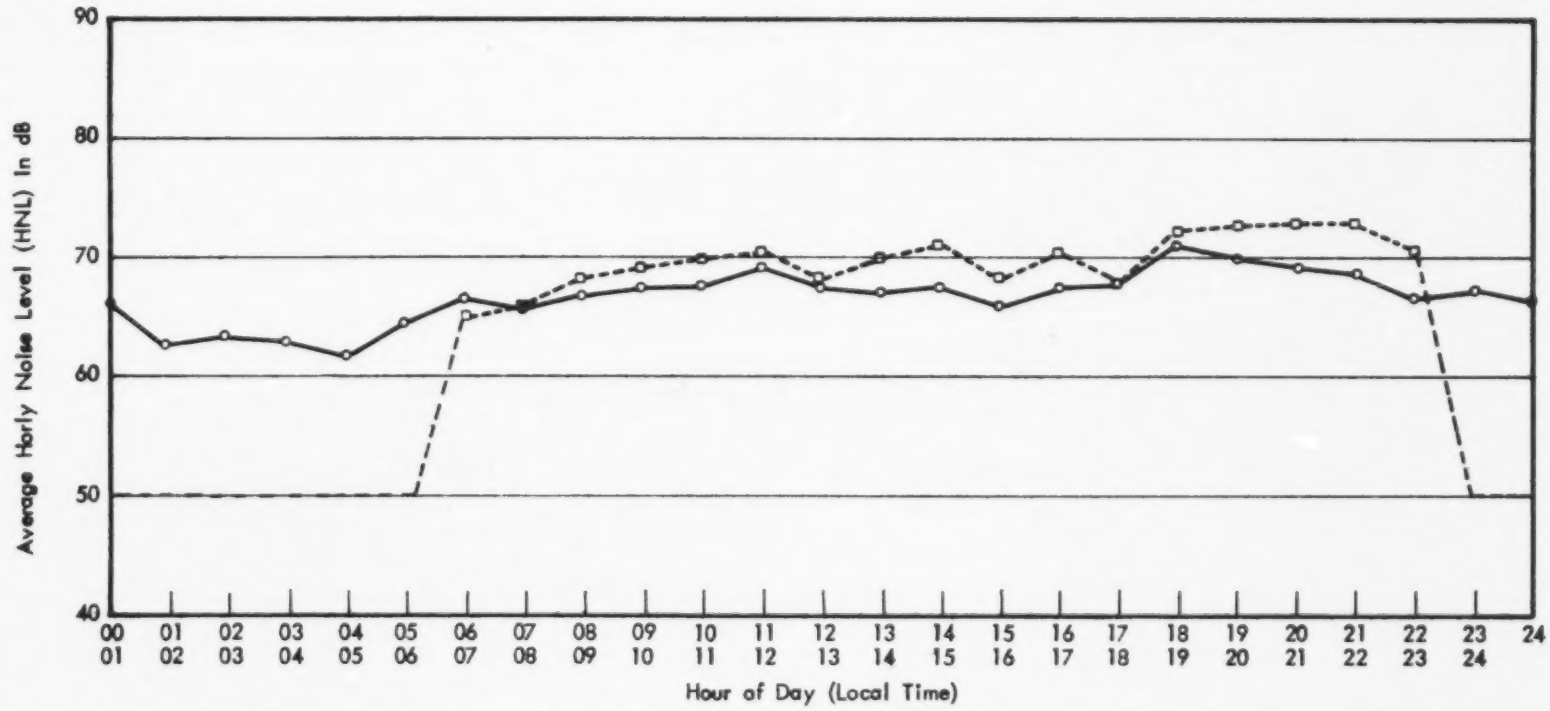


FIGURE 6. VARIATION IN HOURLY NOISE LEVEL FOR SITE 3

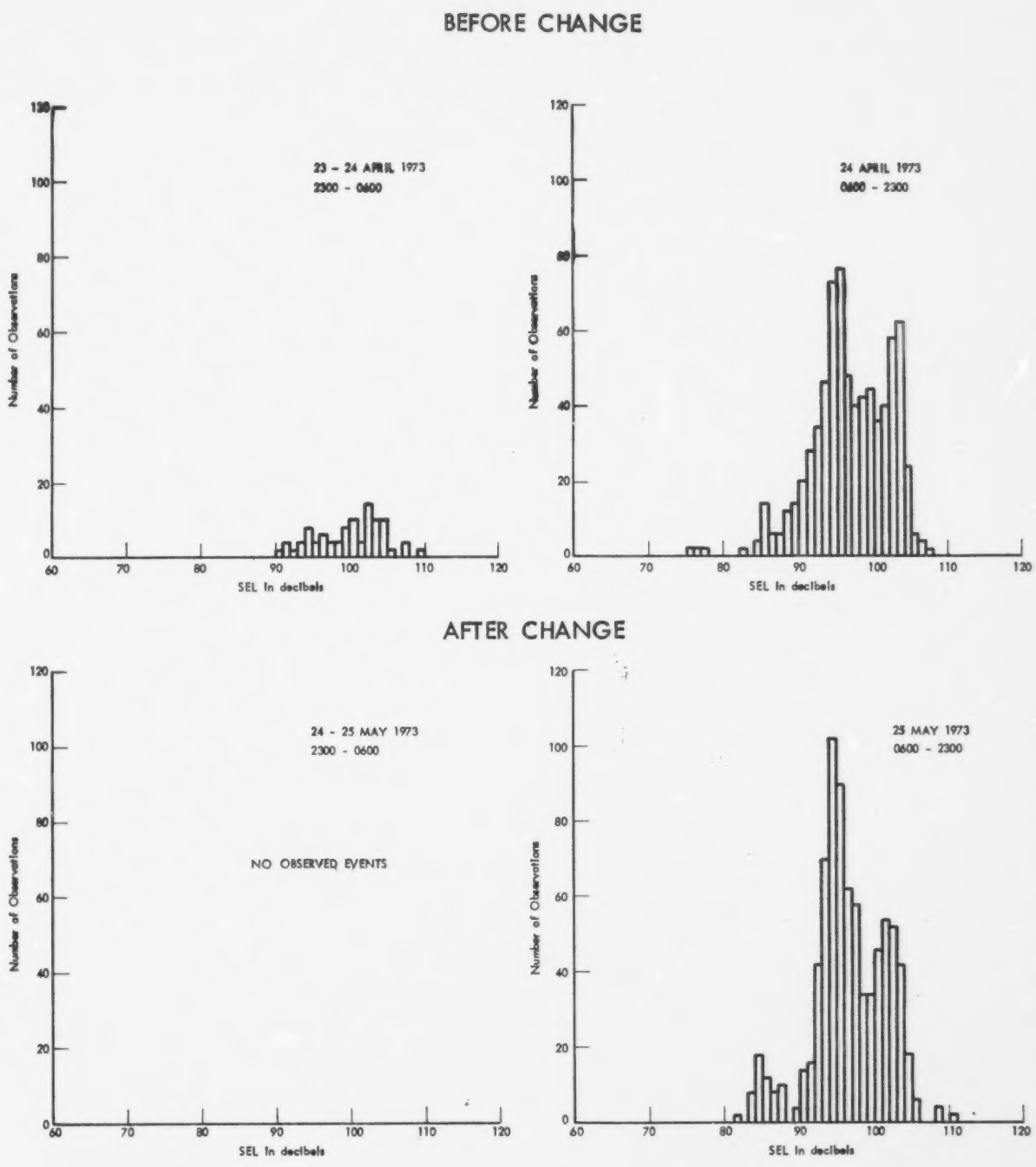


FIGURE 7. DISTRIBUTION OF SOUND EXPOSURE LEVELS AT SITE 1

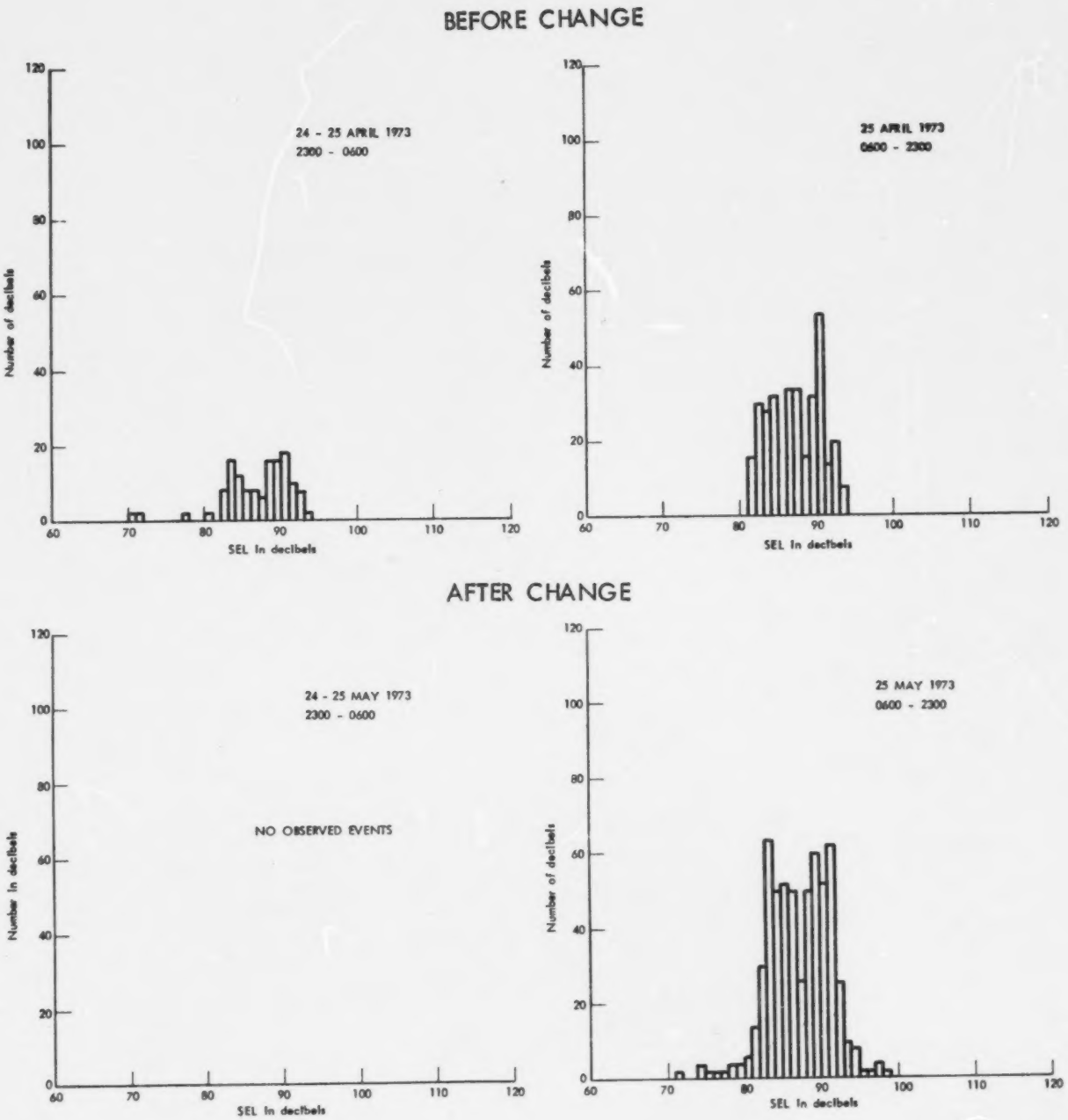
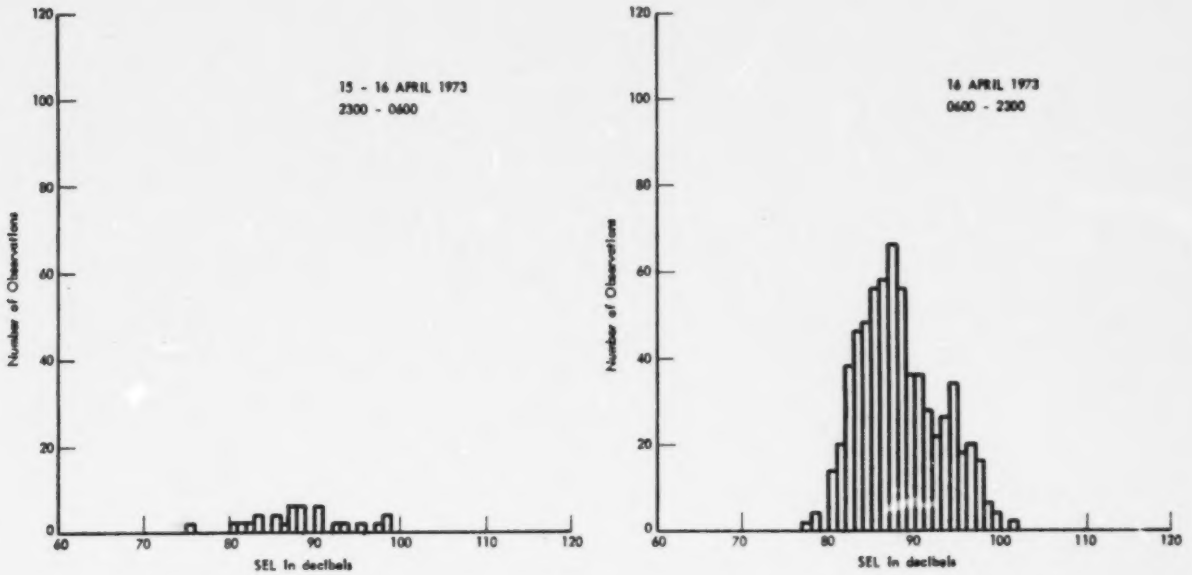


FIGURE 8. DISTRIBUTION OF SOUND EXPOSURE LEVELS AT SITE 2

BEFORE CHANGE



AFTER CHANGE

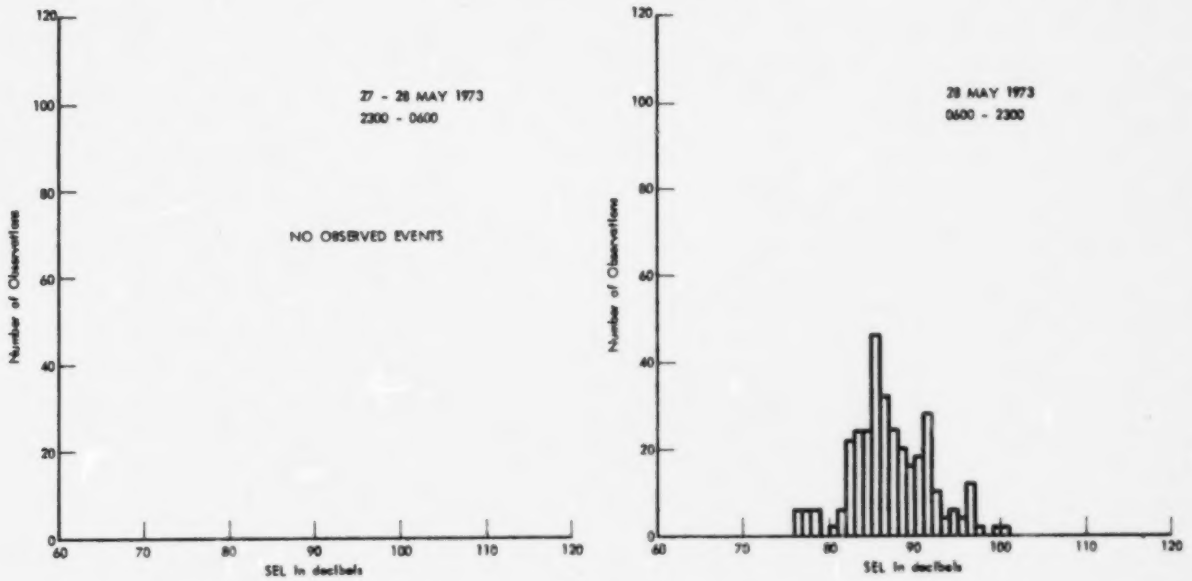


FIGURE 9. DISTRIBUTION OF SOUND EXPOSURE LEVELS AT SITE 3

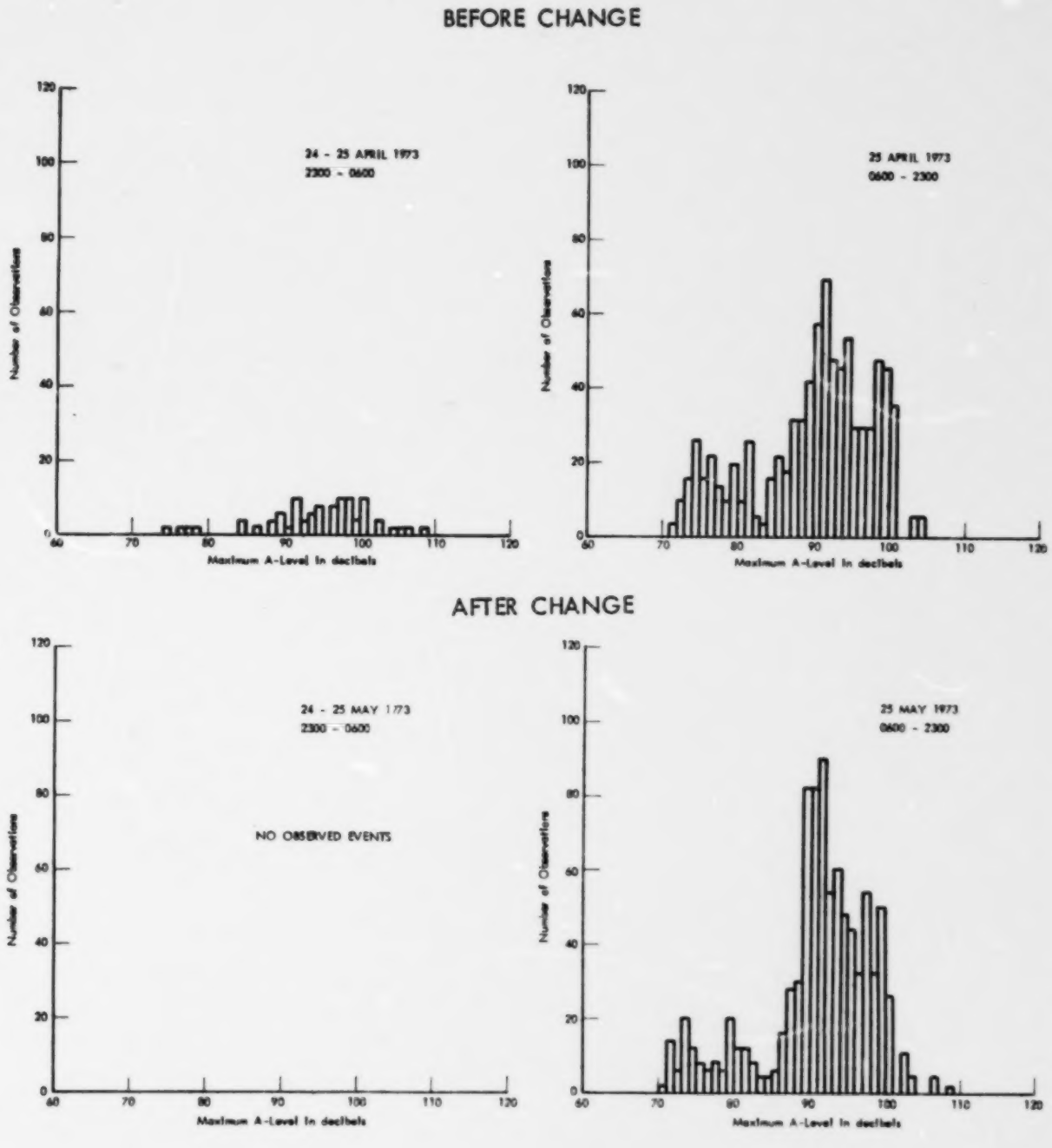


FIGURE 10. DISTRIBUTION OF MAXIMUM A-LEVELS AT SITE 1

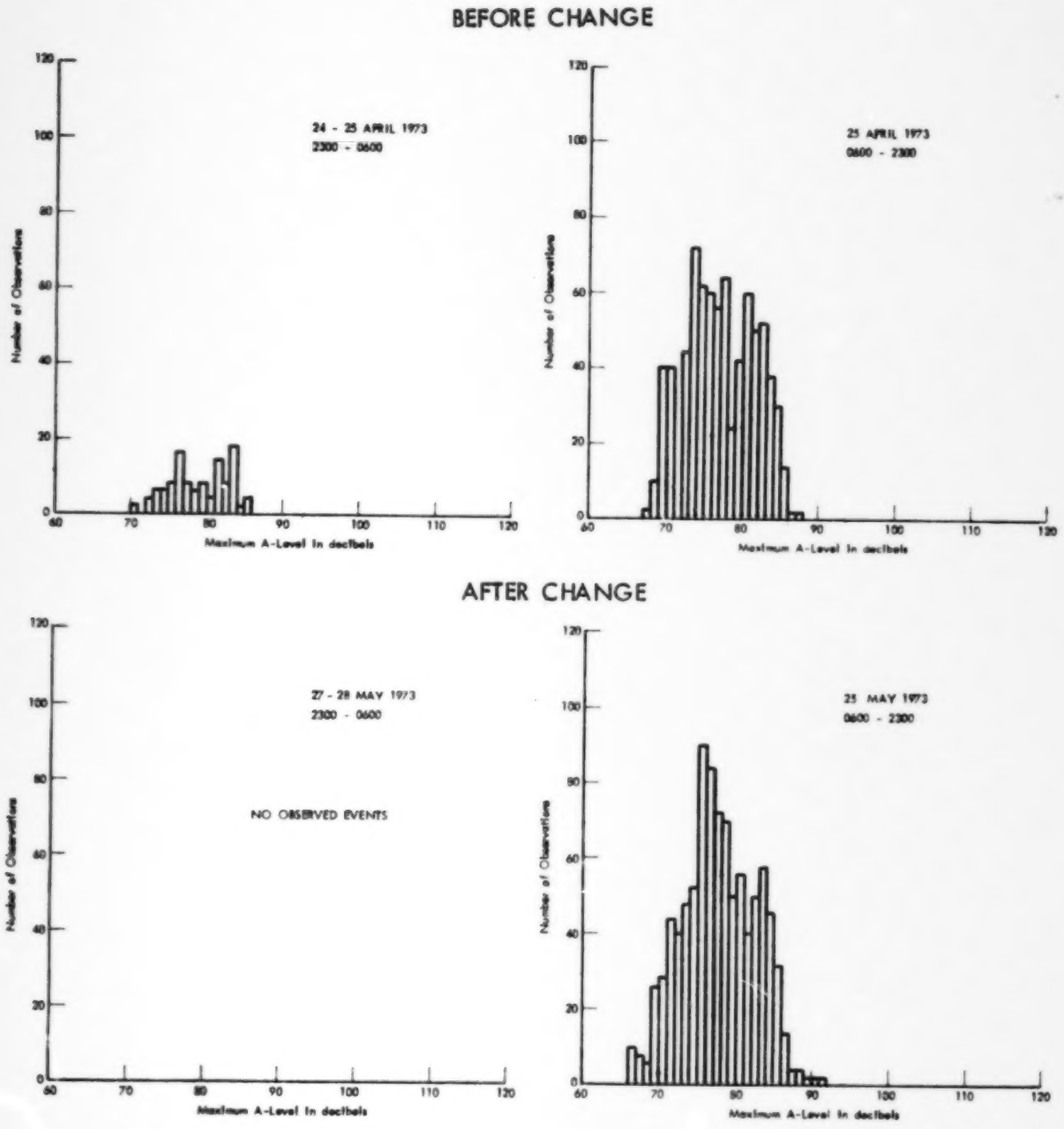


FIGURE 11. DISTRIBUTION OF MAXIMUM A-LEVELS AT SITE 2

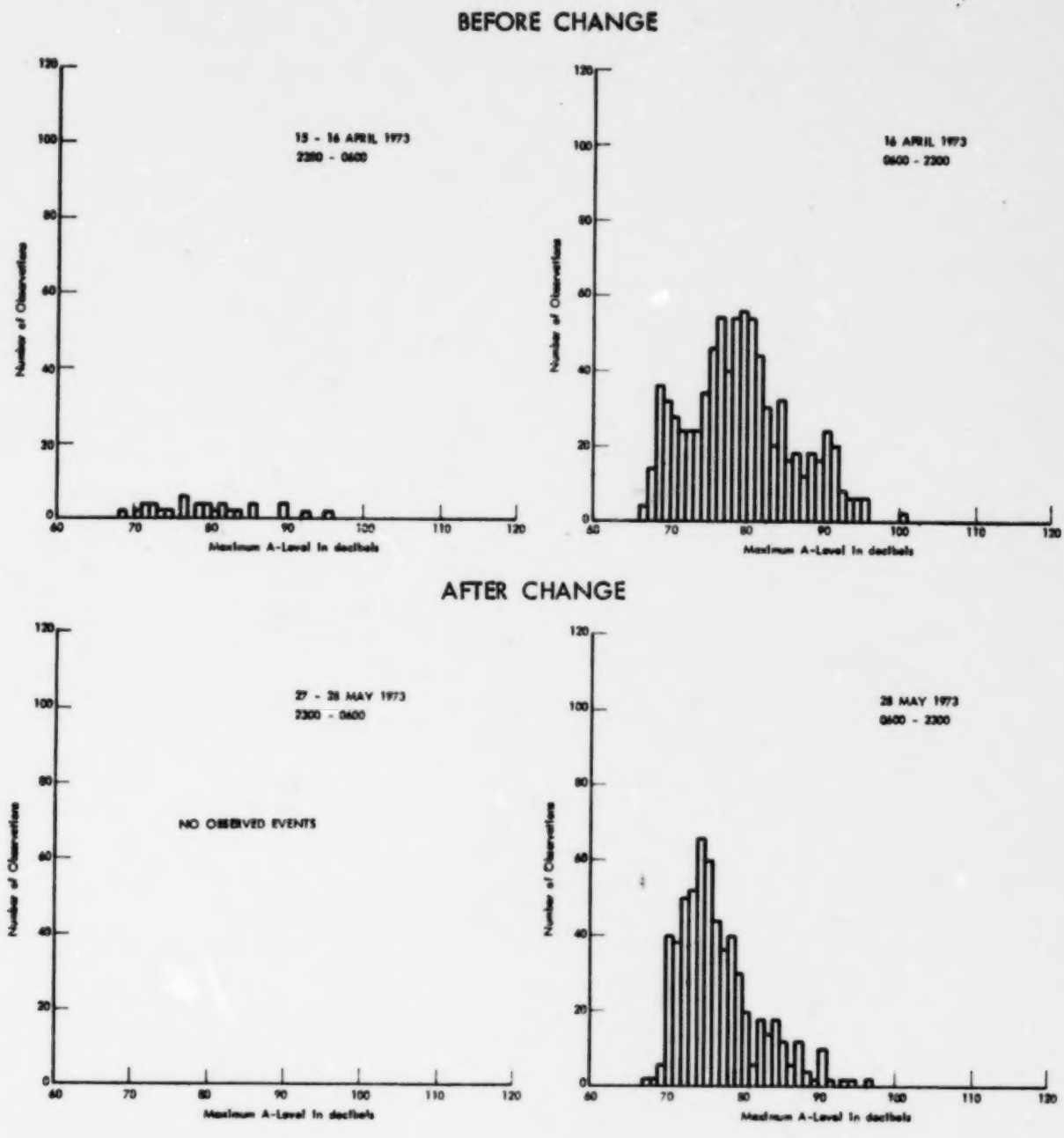


FIGURE 12. DISTRIBUTION OF MAXIMUM A-LEVELS AT SITE SITE 3

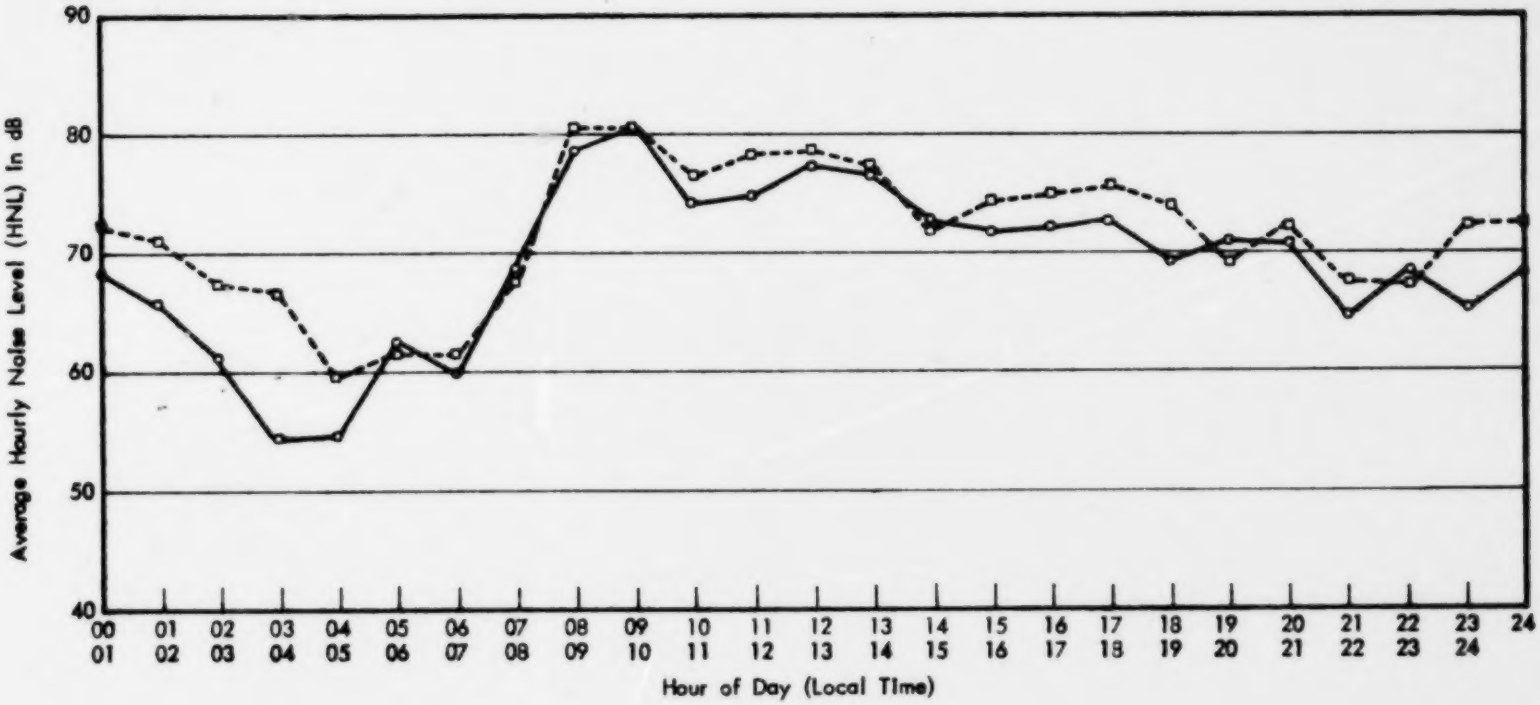
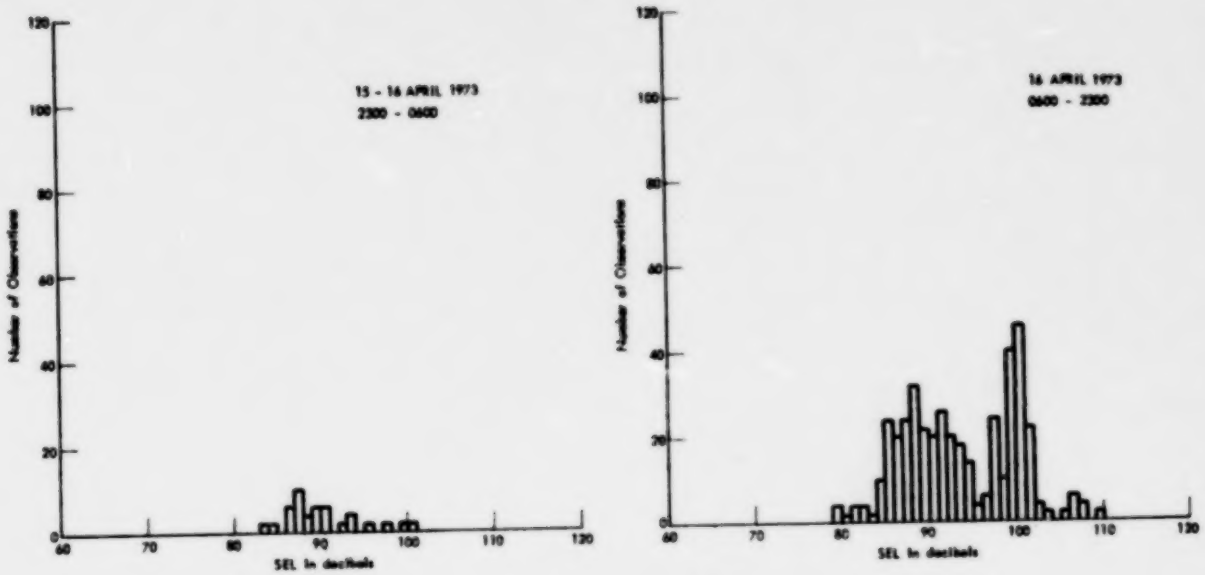


FIGURE 13.. VARIATION IN HOURLY NOISE LEVEL FOR SITE 4

BEFORE CHANGE



AFTER CHANGE

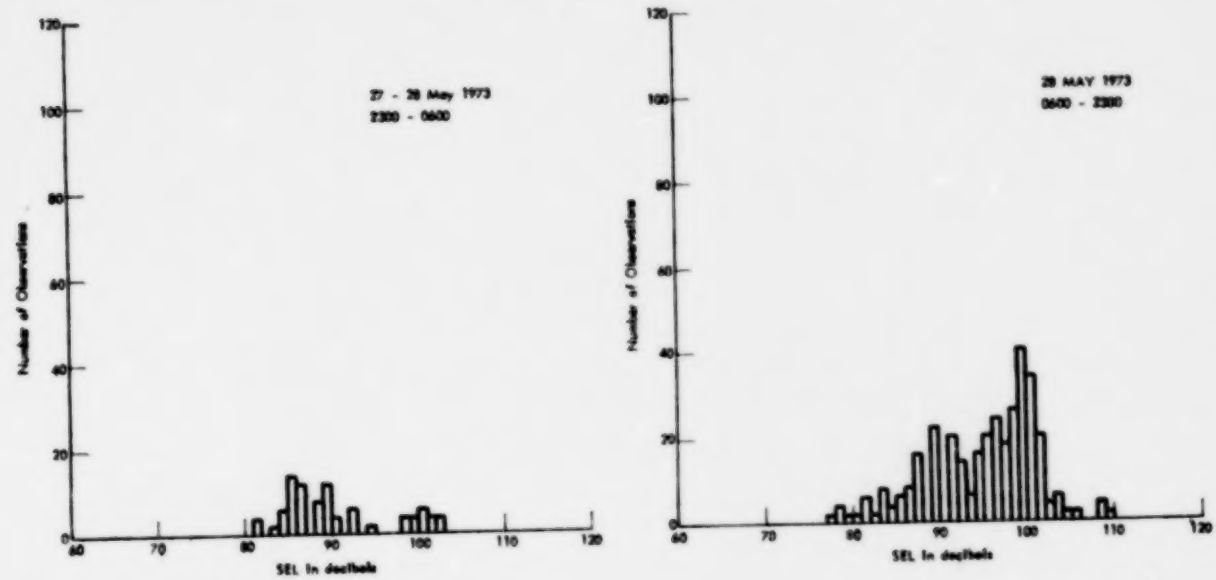


FIGURE 14. DISTRIBUTION OF SOUND EXPOSURE LEVELS AT SITE 4

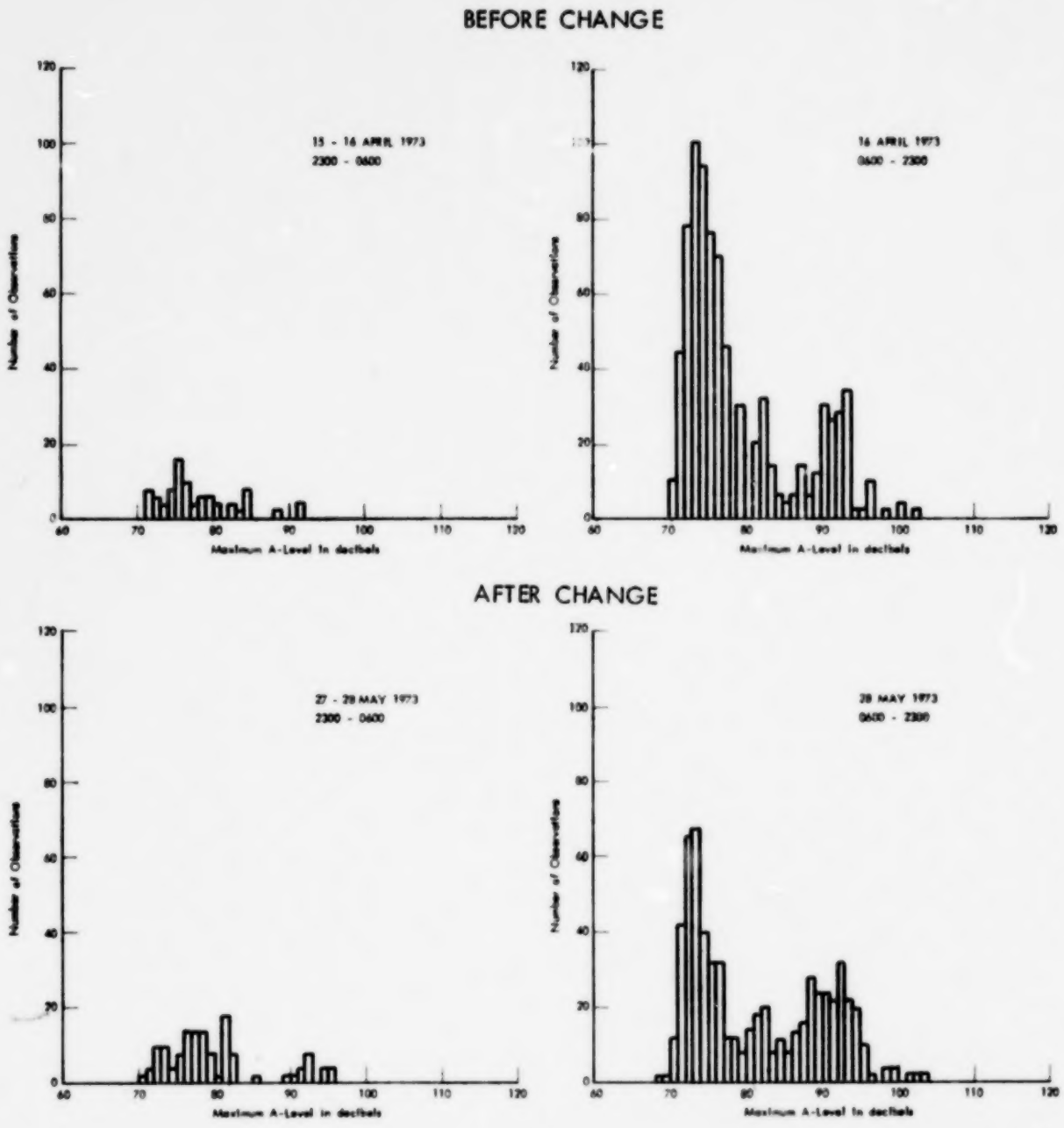


FIGURE 15. DISTRIBUTION OF MAXIMUM A-LEVELS AT SITE 4

REFERENCES

1. "Los Angeles Tower Talk", Volume 6, No. 2, April 1973.

2. "Community Noise Assessment, Ocean Approaches at Los Angeles International Airport", BBN Report 2418, December 1972.

3. D. E. Bishop, M. A. Simpson, "Noise Exposure Forecast Contours for 1967, 1970, and 1975 Operations at Selected Airports", FAA NO-70-8, 1970.

APPENDIX A

NOISE DATA ACQUISITION REDUCTION AND ANALYSIS

The basic noise data acquisition and data reduction system utilizes a number of portable noise monitor systems to record the noise data and a single mini-computer to perform the data processing function. Each noise monitor records noise information on digital magnetic tape. These tapes are returned to the laboratory where they are read by a digital computer which provides printed summary reports of the noise environment.

A. Data Acquisition

The noise monitor units used in this study were developed by BBN and are designed to operate unattended for periods of 24 hours or longer and provide the capability of obtaining long-term noise exposure documentation in a timely and efficient manner.

Each of the systems is completely self contained and is powered by a single 12 volt storage battery. Figure A-1 shows a block diagram of the noise monitor instrumentation. Each system is comprised of (1) a microphone and preamplifier, (2) a monitor control unit, and (3) a digital magnetic tape unit.

The microphone is a General Radio, one-inch ceramic microphone (Model 1560-P5). This microphone was chosen for its ability to operate during damp or rainy weather. The microphone was coupled to a General Radio preamplifier (Model 1560-P40 or Model 1560-P42). The microphone and preamplifier were protected

from wind and dust by an Electrovoice open cellular foam windscreen (Model 355). Use of this windscreen results in a negligible effect (less than 0.5 dB) on the recorded noise levels. At each measurement location the microphone and preamplifier were located atop an eight foot high pole.

The noise signal from the microphone preamplifier was fed to a sound level monitor unit (BBN Model 704) which consists of an amplifier, a frequency weighting network, a logarithmic detector unit and an analog-to-digital converter. Inside the monitor unit, the signal first passes through a standard A-weighting filter, and then goes to a rms (root-mean-square) detector. The detector has a dynamic range of 100 dB and the averaging characteristics conform to those of the "slow" meter setting of a standard sound level meter. The output of the rms detector is a dc voltage proportional to the rms signal input. From the detector the signal goes to a threshold comparator. The comparator detects whether or not the sound level has exceeded a preset threshold level. Typically, the threshold value is selected to just exceed the ambient noise level at the particular noise monitoring site.

If the sound level is below the threshold, the monitor remains in a quiescent state and no permanent record of the sound level is kept. When the threshold is exceeded, the signal passes to an analog-to-digital converter and the sound pressure level is written on digital magnetic tape. As long as the threshold is exceeded, the monitor system continues to record the A-weighted sound level at the rate of one reading every one-half second. When the sound level drops below the threshold, the monitor system ceases to record sound level data, but records the time of day on the digital tape before returning to the quiescent state. Thus, only significant noise events and their tire of occurrence are recorded.

The monitor system determines the sound pressure level to an accuracy of 0.1 dB. However, recording of the 0.1 dB digit on tape can be suppressed in order to extend the amount of sound level information which can be recorded on a given length of the digital tape. When operating in such a mode the recorded sound level is truncated to the next lowest decibel. All data for this survey (with the exception of the calibration signal) were recorded to one decibel accuracy. As a consequence, noise level indices computed directly from this data will be biased downward by 0.5 dB. All measured sound level information presented in this report has been corrected for this bias.

Instrument calibration and system checks were performed on a daily basis. End-to-end acoustic calibration was performed using a General Radio Acoustic Calibrator (Model 1562A). With the calibrator placed on the microphone, the calibration signal was recorded on the digital tape to the nearest 0.1 dB. The recorded calibration signal was later analyzed during data reduction as a check on system performance and as a calibration standard for the noise data.

B. Data Reduction

The noise monitor systems record <u>all</u> transient noise intrusions to which they are exposed. The recorded data is then processed by a small digital computer (Digital Equipment Corporation PDP-8). The computer performs the necessary computations to determine the noise indices of interest in this study. A typical listing of this summary is shown in Figure A-2. The listing first identifies where and when the data was obtained. It then shows the acoustic calibration sequence to confirm that the unit was properly calibrated in the field.

The recorded noise data is synthesized by the computer to a summary description of each noise intrusion. For each intrusion the computer tabulates the time of occurrence, the maximum A-level, the time duration (in seconds) the signal is within 10 dB of the maximum, and the SEL. It should be noted that the column heading "SENEL" in Figure A-2 refers to the Single Event Noise Exposure Level as defined in the California State Administrative Code relating to aircraft noise. For all practical purposes, it is identical to the Sound Exposure Level (SEL) for single noise intrusions.

The computer also tabulates hourly and daily summaries of noise exposure. At the end of each hour the HNL is tabulated immediately following the listing of the various noise intrusions occurring during that hour. At the end of each day (midnight) the DNL value for the day is tabulated immediately following the last HNL value for the day. These tabulations provided the basic data utilized in this study.

C. Analytic Procedures

Sound Exposure Level (SEL) Definition and Computation

In determining people's assessment of aircraft sounds, the intensity, frequency content and duration (length) of the noise signal have been shown to be important attributes. The SEL takes each of these attributes into account by integrating with time the A-weighted sound level. For aircraft flyovers integration is typically performed over the upper 20 dB of the signal.

$$SEL = 10 \log \left[\frac{1}{1 \text{ sec}} \int_{T_1}^{T_2} \text{antilog} \left(\frac{AL[t]}{10} \right) dt \right] \qquad (1)$$

where:

t = time in seconds.
AL[t] = instantaneous A-level at time t, and T_1 and T_2 bracket the time during which the noise signal is within 20 dB(A) of its maximum value.

By virtue of the integration process, the SEL accounts for the duration as well as the magnitude of the noise signal. Thus, it cannot be uniquely correlated with the maximum A-level. However, at distances of the order of 1000 to 2000 feet from an aircraft, the SEL value will be approximately 10 dB greater than the maximum A-level.

Equation (1) defining the SEL implies a continuous time integration of the A-weighted sound level during the time the signal is within 20 dB(A) of its maximum value. However, in utilizing digital techniques, it is desirable to approximate this integral by a summation, replacing dt with a Δt of 0.5 seconds. Noise levels are sampled at 0.5 second intervals and summed according to the following equation:

$$SEL = 10 \log \left[\sum_{i=1}^{n} \text{antilog} \left(\frac{AL_i}{10} \right) \cdot 0.5 \right] \qquad (2)$$

where:

AL_i = A-level for sample i.
n = total number of samples for which the noise level is within 20 dB(A) of the maximum AL_i.

For typical flyover noise signals, random discrepancies of up to ±0.2 dB may occur between the "summation" and the "integral" equations. The mean value of this discrepancy, however, is zero.

Another source of discrepancy, particularly with low level signals, occurs when the signal has less than a 20 dB dynamic range. This can occur for several reasons, the most frequent case being aircraft noise intrusions which do not exceed the ambient noise level by more than 20 dB. The magnitude of this discrepancy may be estimated by analyzing a number of typical flyover noise signals and calculating the SEL from the upper 10 dB as well as from the upper 20 dB of the signal. These comparisons show that the SEL values calculated from the upper 10 dB are typically 0.2 to 1.0 dB less than SEL values calculated from the upper 20 dB of the signal. It should be noted, however, that any bias on the measured DNL due to this phenomenon would probably be negligible unless the majority of SEL's measured at a particular location were subject to this truncation bias.

Average Hourly Noise Level (HNL)

In addition to a descriptor for individual noise events, a measure of hourly noise exposure is frequently useful. Such a measure provides a convenient method for charting the variations in noise exposure over the course of a day's time. The average hourly noise level (HNL) fulfills this purpose by energy averaging the sound level over the course of an hour.*

$$HNL = 10 \log \left[\frac{\int_0^{3600} \text{antilog} \left(\frac{AL[t]}{10} \right) dt}{3600 \text{ seconds}} \right] \qquad (3)$$

*The HNL is identical to the equivalent sound level, L_{eq}, for the hourly period.

where:

t = time in seconds
AL[t] = instantaneous A-level at time t

Equation (3) defining the HNL implies continuous integration over the hour (in a manner similar to equation 1). However, if, during the hour, there is considerable dynamic range to the signal, the lower levels will have negligible influence on the total integral.

For such cases, equation (3) may be rewritten as:

$$HNL = 10 \log \left[\frac{\sum_{i=1}^{n} \text{antilog} \left(\frac{SEL_i}{10} \right)}{3600} \right] \quad (4)$$

For the purposes of this study the HNL was calculated from equation (4).

Day/Night Average Sound Level (DNL) Definition and Computation

The Day/Night Average Sound Level is a measure of noise exposure over a 24-hour period. The DNL accounts for the magnitude of the noise intrusions, as well as the number of intrusions occurring and the time of day in which they occur. The DNL takes these factors into consideration by summing, on an energy basis, each SEL occurring over the course of the day and weighting the SEL value for the time of day the intrusion occurred. The weighting factor accounts for the increased annoyance of aircraft noise during the nighttime hours as follows.

$$DNL = 10 \log \left[\frac{\sum_{i=1}^{n} W_i \cdot \text{antilog} \left(\frac{SEL_i}{10} \right)}{86400} \right] \quad (5)$$

where:

W_i = weighting factor based on time of day SEL_i occurred:

1 for 0700-2200
10 for 2200-0700

n = total number of observed SEL's

86400 = number of seconds in a day

The DNL may also be defined in terms of the average hourly sound level. On this basis:

$$DNL = 10 \log \left[\frac{\sum_{i=1}^{n} W_i \cdot \text{antilog} \left(\frac{HNL_i}{10} \right)}{24} \right] \quad (6)$$

For computations considering specific aircraft events, equation (5) is used. For typical airport monitoring systems where HNL values are regularly determined, equation (6) would be used.

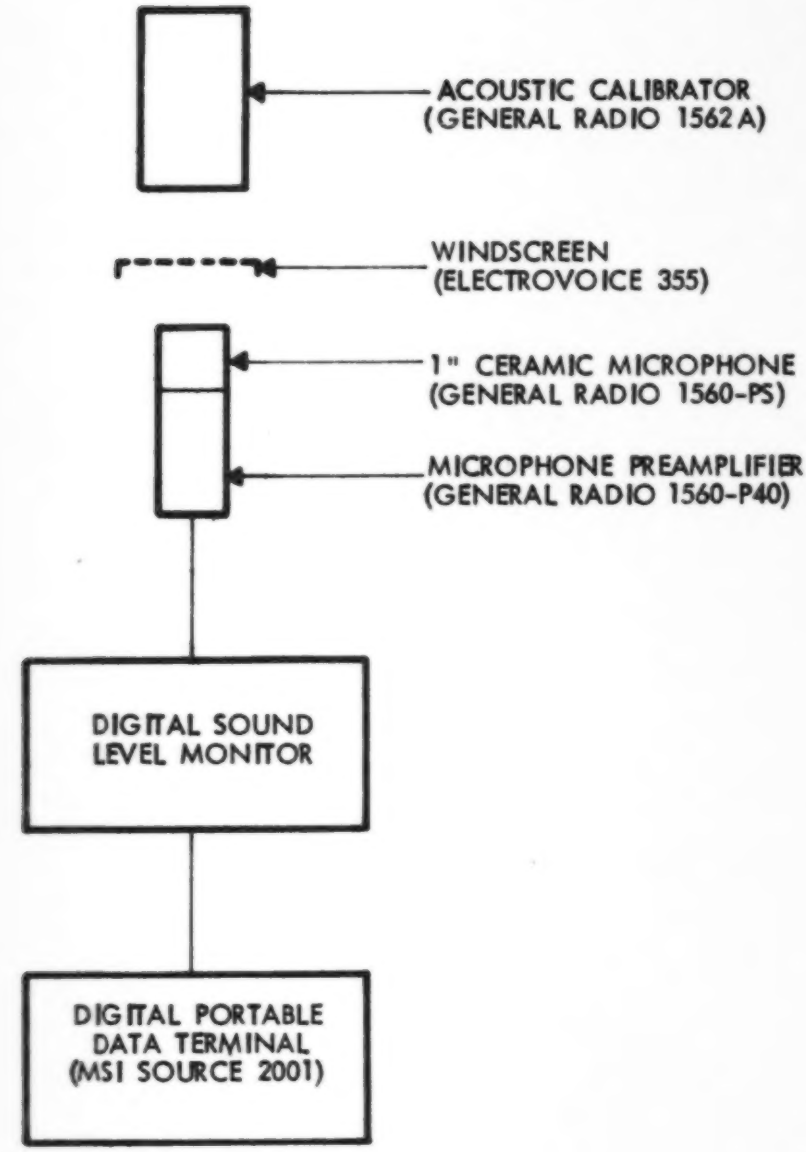


FIGURE A-1. BLOCK DIAGRAM OF NOISE MONITOR EQUIPMENT

```
* UNIT: 4892
* UNIT: 4892
* UNIT: 4892-5
* SITE: 1
* DATE: 17 FEB  1973
* WEIGHTING: LIN
* CALIBRATION:  113.3 113.3 113.3 113.3 113.3 113.3 113.2 113.3 113.2
    113.3 113.3 113.3 113.4 113.3 113.3 113.5 113.4 113.5 113.5 113.6
    113.7 113.7 113.7 113.8 113.7 113.8 113.8 113.8 113.9 114.0 113.9
    113.9 113.9 113.9 113.8 113.9 113.9 113.9 114.0 113.9 113.9 113.9
    114.0 114.0  6-13:26.3
* SITE: 1
* SITE: 1
* WEIGHTING: DBA

    TIME      MAX   DUR  SENEL
   13:32.1   93.0    11  101.2
   13:34.9   75.0    31   86.7
  <13:34.7   68.0     0   66.2
   13:40.2   80.0    30   91.8
  <13:41.7   70.0     3   73.6
   13:42.2   76.0    22   86.6
  <13:45.7   72.0    30   82.7
  <13:50.0   70.0    15   78.2
  <13:50.1   66.0     1   67.2
   13:53.0   82.0    22   92.7
$ HNL (1331 TO 1359) =  67.3

    TIME      MAX   DUR  SENEL
  <14:15.3   71.0    28   82.3
  <14:19.2   70.0    18   80.0
   14:23.2   92.0    21  102.6
  <14:32.7   73.0    42   85.8
  <14:40.5   70.0    22   80.7
   14:45.0   78.0    36   90.6
   14:47.4   82.0    23   92.4
  <14:54.9   70.0    16   79.7
$ HNL (1400 TO 1459) =  67.9
```

FIGURE A-2. TYPICAL LISTING OF AIRCRAFT NOISE LEVELS